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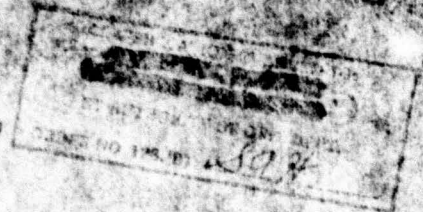
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REPORT NO. 648/2



WATER TOWN ARSENAL

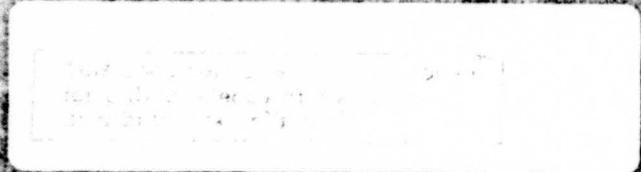
1/2" ARMOR PLATE (HOMOGENEOUS)

ARC WELDED BUTT JOINTS

By

W. L. Warner
Welding Engineer

WATER TOWN



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March 27, 1939

WATERTOWN ARSENAL1/2" ARMOR PLATE (HOMOGENEOUS)ARC WELDED BUTT JOINTS

This report covers the welding and testing of five arc welded butt joints in 1/2" homogeneous armor plate, of the following composition -

C	Mn	Si	S	P	Mo	Cr	Va
0.46	0.57	0.305	0.018	0.012	0.70	1.16	0.25

Conclusions

1. The use of auxiliary connecting members, welded to the armor plate prior to tempering, permits of welding the joint after tempering without bringing the weld metal in contact with the tempered plate.
2. This procedure permits a butt joint to be made by welding without sacrificing any of the ballistic properties of the tempered armor plate at the joint or adjacent to it.
3. By using an overlay of austenitic weld metal on the armor surface, a slight improvement in ballistic properties of the joint seems to be effected over that -> next

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obtained when the overlay is not used and the welding is performed directly on the tempered plate surface.

4. There appears to be less tendency for the weld metal to crack when the austenitic weld metal overlay is used on the armor plate surface than when no overlay is used.

5. With the ^{half inch} ~~1/2"~~ thick auxiliary connecting members butt welded and no weld between the abutting armor edges, a ballistic strength very close to that of 1" thick armor is obtainable and the welding problem is simpler than when the weld is made between the abutting armor edges only.

Welding Data

The type of joint and details of construction are shown by Fig. #1. The welded specimens each consisted of two plates, 9" x 18", put together to make one plate, 18" x 18", with a butt joint 18" long.

Specimens #A1, A2 and A3 were respectively beveled as shown by #1, #2 and #3 of Fig. #1. In each case the plate edges forming the bevel were covered by a layer of stainless steel (25% Cr. - 20% Ni.) deposited in single beads by a 5/32" Murex electrode with the armor plate in the "annealed" condition. This stainless steel layer is estimated to have been about 1/8" thick.

The plates were then quenched and drawn for tempering of the armor and welded together as shown by Fig. #1. Three layers of 25/20 stainless steel were used, two for the backing bead and one in the weld groove, and then two layers of Hollup #450 selfhardening weld metal were applied to complete each weld. By this procedure it is estimated that about half of the plate thickness in the weld consisted of the Hollup selfhardening weld metal. The welds were ground off approximately flush with the plate surface.

When depositing the #450 selfhardening weld metal the deposit of each electrode was cooled off by pouring on water until steaming stopped. This procedure prevented the armor from becoming excessively hot alongside the weld which lessened the danger of drawing the temper of the plate in the heat affected zone.

In the welding data tabulation which follows, the welding operations are listed in the order in which they were performed.

Weld	Amps.	Volts	Layer	Separation	Remarks
A1	130	25	1st Backing Bead	1/8"	Electrode
	150	27	2nd " "		5/32" Murex 25/20 Cr.-Ni. Joint upside down

Plate turned over and weld groove cleaned by chipping

Weld	Amps.	Volts	Layer	Separation	Remarks
	150	26	1st		Electrode 5/32" Murex 25/20 Cr.-Ni.
	150	25	2nd		Electrode 5/32" Hollup.
	150	25	3rd		#450 selfhardening Electrode same as 2nd layer.

Ground weld flush with the plate surface.

A2 and A3 - A similar procedure was followed.
(See Fig. No. 1)

Specimens A4 and A5 involved the use of auxiliary members of structural low alloy steel which were welded to the armor plates before tempering. The form is shown by Fig. #1 at 4 and 5.

The auxiliary members B are 1/2" Yaloy (2% Ni., 1% Cu., 0.15% C.). The welds D were made with 5/32" Lincoln Shield-Arc #85 as were also the plug welds shown in 4. The Yaloy strips B of specimen 5 are 2" wide, while those of specimen 4 are 3" wide to allow space for the plug welds indicated.

After tempering the armor plate the welds E were made with 5/32" Shield-Arc #85 connecting the Yaloy strips as shown in Fig. #1. By this procedure there was no welding performed on the hardened or tempered armor plate.

Ballistic Tests

These five welded joints were tested at Aberdeen Proving Ground in January, 1939, the results of which

are given in the "127th Partial Report on Test of Thin Armor Plate", dated Jan. 26, 1939.

From this report the following extracts have been taken.

"In those plates which were backed by reinforcing strips, it was found impossible to effect penetration with caliber .30 in the reinforced area."

"Range to plate was 100 yards. Plates were normal to the direction of fire."

The following ballistic limits were obtained for the five welded joints as quoted from the above report.

<u>Ballistic Limits - Foot Seconds</u>					
	<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>A4</u>	<u>A5</u>
<u>Cal. .30 A.P.</u>					
Weld	2295	2324	2368	-	-
Plate, within 1"					
of weld	2688	2560	2609	-	-
Plate, 1" or					
more from weld	2576	2591	2653	2526	2523
<u>Cal. .50 A.P.</u>					
Weld	-	1325	-	2650	2615
Plate, within 1"					
of weld	-	1490	-	2566	2653
Plate, 1" or					
more from weld	-	1490	-	-	-

In the test of plates A1 and A3 the test area was used up before limits with the Cal. .50 A.P. could be obtained. A section of A3 broke out after three shots had

been fired with Cal. .50 A.P.

With the other welded joints there was not the tendency, noted on previous tests, for the weld metal to crack out or spall off, and the joints held together in spite of the many perforations caused by the bullet penetration.

It would be of considerable interest to see the welding method used on specimens A4 and A5, also tried out on 1" thick face-hardened armor plate with the 1/2" strips for connecting members as used here.

It would appear that the main question at issue on the 1" plate would be whether the welded joint between the 1/2" structural steel plates would stand up under the impact of 37 m/m firing on the joint.

For the purpose of an approximate comparison between these data and similar previous data, the following tabulation is included. It is noticeable that on specimens A1, A2 and A3 the plate does not show any reduction in ballistic limit adjacent to the welds, and that the wide bevel (A3) shows the best B.L. for the joint of these three joints.

Respectfully submitted,

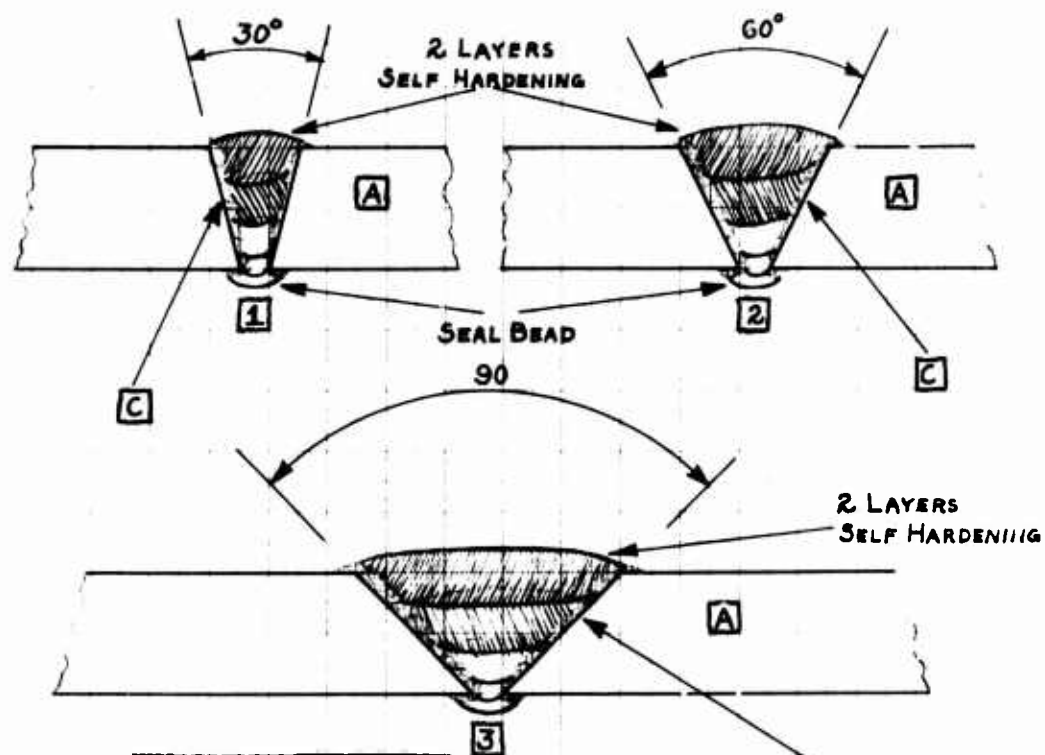

W. L. Warner,
Welding Engineer.

Foot-seconds, Ballistic Limits of Butt Joints - Armor Plate
(Dr. Reed's Records - W.A.)

Aberdeen Report No.	Plate Manufacture	Type of Plate	Plate Thickness	Cal. of Shot	B.L. of Joint	B.L. within 1" of Joint	Ratio		Remarks
							B.L. of Joint to	B.L. of B.L. of Plate as specified	
5/25/38	Disston	Face Hardened	1/2"	.30	2003	2502	2595	82%	Welded by Disston details unknown.
121	M.W. Kellogg	?	9/16"	.50	2084	2112	2121	99.6%	Welded by Kellogg details unknown.
Unwelded Plate			1/2"	.30	-	-	2450	-	Specification - AXS-54K.
Unwelded Plate			1"	.50	-	-	2700	-	Specification - AXS-54K.
127	Jessons	Homo.	1/2"	.30	2295	2683	2576	94%	Specimen A1 - straight butt - Ni. Cr. single layer overlay.
Watertown Welds				.30	2724	2560	2591	95%	Specimen A2 - straight butt - Ni. Cr. single layer overlay.
				.50	1325	1490	1490	-	Specimen A3 - straight butt - Ni. Cr. single layer overlay.
				.30	2367	2609	2653	97%	

Aberdeen Report No.	Plate Manu- facture	Type of Plate	Plate Thickness	Cal. of Shot	B.L. within		B.L. of B.L. of Plate as specified	Ratio B.L. of Joint to	Remarks
					B.L. of Joint	1" of Joint			
127	Jessops	Homo.	1/2"	.30	-	-	2526	-	Specimen A4 - 1/2" reinforcing strips & no weld between armor edges.
				.50	2650	2566	-	93.1%	
				.30	-	-	2523	-	Specimen A5 - same as A4.
				.50	2615	2653	-	96.3%	

Watertown Welds



WATERTOWN ARSENAL
ARMOR PLATE TESTS
ARC WELDED
BUTT JOINTS

A - ARMOR
B - STRUCTURAL PLATE
C - 25/20 CR-NI OVERLAY WITH ARMOR ANNEALED
D - COMM. ALLOY ROD (MO. STEEL) WELD MADE WITH ARMOR ANNEALED

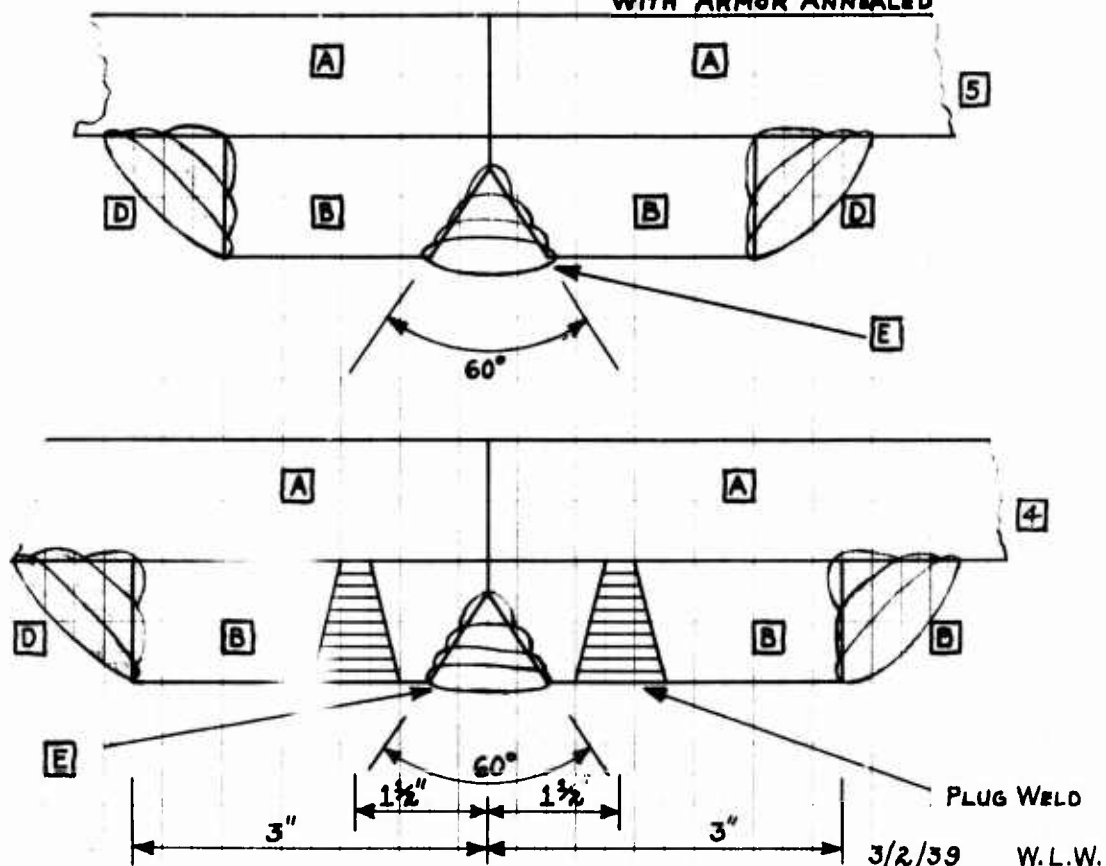


FIG. No. 1.